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EMISSIONS FROM THE WORCESTER POLYTECHNICAL INSTITUTE (WPI) HYBRID

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Environmental Protection Agency
Ann Arbor, Michigan

October 1971

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16. Abstracts

A thorough evaluation was conducted of the Worcester Polytechnic Institute Electric Hybrid, which was entered in the 1970 Clean Air Car Race and was the winner of the Hybrid Division of the race. The report describes the control techniques which are incorporated in this electric car and describes the testing program which basically uses the 1972 and 1970 Federal Test Procedure. The mass emissions data, which is tabulated, were relatively high. This may have been due to failure or poisoning of the catalysts or to malfunction of the air pumps or EGR systems.

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Hybrid propulsion
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Carbon dioxide
Carbon monoxide
Hydrocarbons
Nitrogen oxides

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Worcester Polytechnical Institute Hybrid
Federal Test Procedure (1972)
Federal Test Procedure (1970)

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Background

The WPI Electric Hybrid was entered in the 1970 Clean Air Car Race by students from Worcester Polytechnic Institute and was the winner of the Hybrid Division of the Race. A contract was arranged so that the car could be more thoroughly evaluated, using the 1972 Federal Test Procedure, at EPA facilities in Michigan.

Control Techniques

The WPI Hybrid is basically an electric car with on-board charging capability. Power is stored in 20 six-volt batteries wired in series, and is transmitted via a DC traction motor and heavy duty propeller shaft and differential to the rear wheels. The generator for recharging the batteries is powered by an internal combustion Jeep V6 engine of 225 cubic inch displacement. Emission controls on the engine include air injection into the exhaust manifolds, catalytic reactors, and exhaust gas recirculation. The engine burns lead-free gasoline to protect the catalysts.

Engine speed is maintained between 1800 and 2200 rpm. The loan on the engine is also kept relatively constant because the demands for power, such as during accelerations, are met by drawing from the batteries. Such a design has the potential to produce low emissions.

The vehicle weighed about 4500 pounds and was tested at an inertia weight of 4500 pounds.

Test Program

The vehicle was delivered to the EPA laboratory at Willow Run Airport on April 7, 1971. The students who delivered the car demonstrated the vehicle operating procedures to OAP test personnel. Dynamometer testing required a driver to follow the speed-time schedule and another person to control engine speed and various electrical parameters. Testing concluded on May 8 due to increasing amounts of heat and smoke from the vehicle's electrical apparatus.

The car was run on the 1972 Federal Test Procedure and on the 7-mode procedures using an inertia weight of 4500 pounds. The 1972 FTP is a chassis dynamometer procedure consisting of a cold start, the LA-4 driving schedule and the constant volume sampling (CVS) method for collecting a diluted sample of the exhaust over the entire start and driving operation.

The 7-mode procedures employ a repeating 7-mode driving cycle. The 1970 Federal Test Procedure uses continuous analysis of the undiluted exhaust over seven repeats of the cycle. The emission concentrations are averaged at several discreet intervals during each cycle and then multiplied by factors reflecting fuel-air ratio, engine air flow rates and time in each mode during actual driving to yield an average concentration during each cycle. The mass emissions are calculated from the concentration data using a formula based on vehicle weight. The 9 x 7 test uses nine repeats of the 7-mode cycle, with the CVS method of sample collection.

In the 1970 FTP, all exhaust constituents are analyzed by NDIR instruments. In the CVS procedure NDIR is used for determining CO and CO_2, a flame ionization detector (FID) for unburned hydrocarbons (HC) and a chemiluminescence (C.L.) instrument for nitrogen oxides (NO_x).

Results

The mass emissions data, presented in Table 1, were relatively high. This may have been due to failure or poisoning of the catalysts or to malfunction of the air pumps or EGR system. The high emissions could also have been caused by a malfunction of the electrical controls resulting in the I. C. engine being operated at too high a load or at some other non-optimal condition.

Mass emissions of NO_x from the C. L. instrument are presented as NO_2, corrected to a humidity of 75 grains. On test number 12-1521, the lower HC emissions are due to the fact that it was a hot start test.

TABLE 1

WPI Electric Hybrid

Mass Emissions

Test No.	Type	HC gm/mile	CO gm/mile	CO_2 gm/mile	NO_x gm/mile
12-1456	72 FTP	3.46	12.06	1053.2	6.53
12-1457	72 FTP	5.84	11.04	1182.7	6.94
12-1502	72 FTP	1.08	20.39	1763.8	11.26
12-1520	72 FTP	1.14	15.68	1542.0	11.44
12-1521	72 FTP Hot Start	.32	15.12	1707.0	12.00
12-1567	9 x 7	2.85	3.99	869.6	13.82
6-0632	70 FTP	.35	1.27		9.16*

* NO only, determined by NDIR.